A Study of Unsaturated Flow in Porous Media for a Thermally Perturbed Scenario Using Experimental and Numerical Models

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Understanding the evolution of the environment within the emplacement drifts of a potential high-level nuclear waste repository at Yucca Mountain, Nevada, is challenging, because of the heterogeneity of the natural system, the interactions between the engineered and natural components, the unsaturated flow conditions at the repository horizon, and the potential for drift degradation in a thermally perturbed state. The quantity and chemistry of seepage water and the in-drift thermohydrological conditions are two important factors that can affect the initiation and duration of the degradation of waste packages or drip shields.

This paper presents preliminary results of a phased study that involves numerical and experimental models to simulate the thermohydrological-chemical environment at the potential repository site. The study was designed to integrate the unsaturated flow processes during the thermal period with geochemical and corrosion processes. In the first phase of the study, a two-dimensional numerical model (MULTIFLO 2.0.1) was developed to simulate coupled heat and fluid flow in unsaturated porous media. In addition, an experiment was designed and conducted to simulate the near-field and in-drift unsaturated flow conditions at the potential repository. During the experiment, measurements were made linking temperature, relative humidity, and chemistry of water contacting the surfaces of engineered materials. The objective was to better understand the relationships among the evolution of water chemistry, temperature, relative humidity, infiltration flux, and corrosion of waste package and drip shield materials. The numerical model was used to determine the dimensions of the experimental setup, suitable heat flux, and appropriate infiltration flux rates. The numerical model was also used to simulate the experiment, and the results were compared to the experimental measurements. The comparisons between the numerical predictions and experimental measurements will be discussed, as well as the validity of assumptions concerning unsaturated flow processes (e.g., flow focusing). In later phases of the study, the effects of coupled thermohydrological-chemical conditions on corrosion processes and drift degradation will be investigated.

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